Influence of Ink Viscosity level on Tone Value Increase in Sheet-fed Offset Printing

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Abstract:

Purpose - Dot gain is caused by ink spreading around halftone dots. Several factors can contribute to the increase in halftone dot area. As printing pressure can squeeze the ink out of its dot shape causing gain, ink viscosity is a contributing factor with coated papers, higher viscosity inks can resist the pressure better than lowest viscosity ink. Halftone dots can also be surrounded by a small circumference of ink. Each halftone dot has a microscopic relief, and ink will fall off the edge before being eliminated entirely by the fountain solution in the case of sheet-fed offset printing. The lithographic inks behavior necessitates viscosity measurement over the full range of shear rates that inks can encounter in use, this range is very wide since very low shear rates are encountered in removing ink from the can and in the ink duct, whereas exceedingly high rates of shear exist in the roller nips of fast running presses. **The aim of this research** is to determine the influence of the different ink viscosity levels on tone value increase of final prints in sheet-fed offset printing. Design/Methodology/Approach - Three different ink viscosity levels were used with each inking system on each printing unit, to examine tone value increase (dot gain) for sheet-fed offset printing process, measured on matte-coated paper prints. The analysis of tone values results in order to determine their dependency on ink viscosity level and which viscosity level generates the best print reproduction for the tone values. **Findings** - Applied ink viscosity levels influenced tone value, as well as that there was no clear trends of how print quality degrades or improve with the same ink viscosity change for tone value. Obtained mechanical dot gain values on the plates show that all tone values are reproduced correctly, without bigger increases. Taking into account ISO 12647-2:2004 standard, and reference TVI values for the prints, the most appropriate TVI values were achieved by using different ink viscosity levels for different inks, low ink viscosity level produced the best TVI values for magenta ink, normal ink viscosity level showed as a best option for cyan and yellow inks, while high ink viscosity level generated the best results for black ink.

Keywords:

Sheet-fed Offset Printing,
Ink viscosity,
Tone value increase,
Dot gain,
Ink density

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1- Introduction

The changes in dot diameter is the critical factor for the print image transfer, as these changes lead to tone value increase (TVI) and color shifts. Considerable differences in tone value can occur during both plate making and printing and have a detrimental effect on print quality. Constant halftone value transfer can be achieved in plate making and in printing by standardization of the offset process. The blanket and the press setting exert the greatest influence on the transfer of tone values during printing. A change in ink viscosity and tack causes considerable changes in the transfer of tone values.

Dot gain is caused by ink spreading around halftone dots. Several factors can contribute to the increase in halftone dot area. As printing pressure can squeeze the ink out of its dot shape causing gain, ink viscosity is a contributing factor with coated papers, higher viscosity inks can resist the pressure better than lowest viscosity ink. [1] Halftone dots can also be surrounded by a small circumference of ink. Each halftone dot has a microscopic relief, and ink will fall off the edge before being eliminated entirely by the fountain solution in the case of sheet-fed offset printing. The lithographic inks behavior necessitates viscosity measurement over the full range of shear rates that inks can encounter in use, this range is very wide since very low shear rates are encountered in removing ink from the can and in the ink duct, whereas exceedingly high rates of shear exist in the roller nips of fast running presses. [2]

Dot gain is usually positive because the blanket enlarges the dot upon transfer to the paper, the change in tone values resulting from the printing process must be considered for the color separation and film making. Dot gain essentially depends on the papers surface, its absorption, ink setting behavior, ink viscosity and tack, blanket and printing pressure. [3]

The aim of this research is to determine the influence of the different ink viscosity levels on tone value increase of final prints in sheet-fed offset printing.

This research is structured in the following: Section 2 is a literature review, which includes the theory of area coverage, dot gain, ink viscosity and tack. Section 3 solid tone ink density and tone value measurements on matte-coated prints. Section 4 Analysis of the effects of different ink viscosity levels on tone value increase. Section 5 is the conclusion.

2- Literature Review

2.1. Ink Viscosity

Viscosity is defined as the ratio of shearing stress (shearing or deformation force per unit area) to shearing rate (velocity gradient of flow order deformation). Lithographic inks are substantially non-Newtonian as this ratio is not constant but is shear-rate dependent. This is primarily due to the high content of dispersed pigment present. The non-Newtonian behavior necessitates viscosity measurement over the full range of shear rates that inks can encounter in use. This range is very wide since very low shear rates are encountered in removing ink from the can and in the ink duct, whereas exceedingly high rates of shear exist in the roller nips of fast running presses. Consequently, it is not normally possible to measure viscosity under all relevant conditions on a single viscometer. A variety of techniques are employed. The two most common instrument types are the falling rod viscometer for high shear rates, and the cone and plate viscometer for lower shear conditions. [3]

2.2. Ink Tack

Tack is a measure of the forces required to split a single film of ink into two. Such film splitting is influenced by rheological and adhesive properties, in addition to the internal cohesion of the ink. Various instruments have been developed to measure tack but all rely on the principle of measuring the force exerted on a roller as it splits a single ink film in a nip into two films at the nip exit. [4]

A subjective, comparative assessment of tack can be made using fingertips to separate a thin film of ink on a slab into two films, one portion remaining on the slab and the other adhering to the fingertip. A skilled technician, using repetitive dabbing of two inks with adjacent fingers, can make a surprisingly good comparison in this way. However, the method suffers the disadvantages of all such approaches which depend on individual skill and which do not produce a quantitative result.

Tack does not vary as rapidly with temperature as does viscosity. Nevertheless, there is an influence and all competent tack measuring devices incorporate appropriate temperature control of the roller system. As an empirical quantity, tack can be significantly influenced by film thickness and it is important that the volume of ink applied to tack measuring devices is carefully controlled. Even with temperature and film weight control, different tack machines can produce different results on given inks. [3]

3- Materials and Methods

This research includes examination of tone value increase (dot gain) for sheet-fed offset printing process, measured on matte-coated paper prints using three different levels of ink viscosity on each inking system in sheet-fed printing process, low ink viscosity, normal ink viscosity and high ink viscosity.

3.1. Ink Viscosity Measurements

Three different ink viscosity levels were used with each inking system on all printing units, to examine tone value increase (dot gain) for sheet-fed offset printing process, measured on matte-coated paper prints.

Total circulation of 300 sheets were printed by sheet-fed offset Heidelberg SM 52-4, 4 colors with Baldwin cooling and alcolor dampening. [2] Using S7400 blanket from Kinyo, Chiara fount plus dampening from imaf, TPS positive thermal CTP plate from Jinrutaitechnology (circular dot shape, AM screening) and Smart Line process inks from Beckmann on matte-coated paper (165 g/m2), under ideal atmospheric printing conditions in the press room (relative air humidity of 55% and air temperature of 23Â°C) under printing speed of 7.000 sheets/h. Ink sequence was black, cyan, magenta and yellow (KCMY). Before printing of the actual job, printing machine was brought in an optimal state by printing approximately 100 sheets in order to set inking units.

When the job was printed a random sampling of the prints took place and three sheets were taken for each printing pressure level applied. When the printing pressure measurements and printing of the samples were done.

3.2. Solid-Tone Ink Density Measurements

Solid-tone ink density measurements were obtained using Spectro Eye-X-rite (applied setting: Profile size - large, Perceptual rendering intent - paper, Gamut mapping - Logo classic, Separation - GCR 40 -100 - 400 and Viewing light source - D50) on the solid-tone patches, Figure 1.

3.3. Tone Value Increase (TVI) Measurements

Values were measured on tone value patches (patches from 0% - 100% with steps of 10%) of matte-coated prints Figure 1. Using Spectro Eye-X-rite (same settings as mentioned above) Color difference values were calculated using ΔE94 formula, which is a recommendation given by this software.

Figure 1: Measured control elements of the matte-coated paper

4- Results and Discussions

The analysis of tone values results will be presented and discussed in this section of the paper, in order to determine their dependency on ink viscosity/tack and which viscosity level generates the best print reproduction for the tone values.

4.1. Ink Viscosity Analysis

Three different ink viscosity levels were used on each inking unit in the printing process, low ink viscosity, normal ink viscosity and high ink viscosity.

Ink viscosity on each inking unit was uniform as possible, there were (8% - 12%) deviations between them. In wet-on-wet printing on multi-unit presses, it is necessary, in relevant image areas, for ink to transfer or 'trap'on top of a previously printed, wet ink film. If the initial colors printed are very low in tack they may be susceptible to an unacceptable degree of 'back-trapping' from subsequently printed, higher tack, inks. This will occur if less force is required to split the previously printed ink film from the paper than is necessary to split the subsequent ink from its blanket. Naturally, such poor trapping completely disrupts color reproduction and may easily result in an unsatisfactory final print.

Dot gain is also dependent on tack. It is less easy to identify a simple explanation for this effect but it seems possible that the low cohesion of dots of low-tack ink provides less resistance to the squashing action at the plate/blanket and blanket/substrate impression nips. Thus, excessively low tack inks may produce unacceptably high dot gain.

4.2. Solid-Tone Ink Density analysis

Standard solid-tone ink density values for sheet-fed offset printing process which are presented in Table 1, were taken as a reference for standard deviations calculations. Average solid-tone ink density values, and calculated standard deviations from the reference solid-tone optical ink density values for each process ink and viscosity levels.

Table 1: Recommended solid-tone ink density values according to ISO 12647-2 [5]

Paper type	Ink			
	Cyan	Magenta	Yellow	Black
Matte-coated wood-free	1.45	1.4	1.25	1.75

It is already observed that when the ink viscosity increases, ink deposition on the substrate will also rise, which results in higher ink density values. By using high ink viscosity in printing process, generally higher solid-tone ink density values were produced.

Standard deviation values show declining trend after the first ink viscosity change from low to normal, Table 2. Normal ink viscosity level generated the smallest solid-tone ink density deviations for three process inks (CMY). With high ink viscosity, standard deviation values went up, with the exception of black ink, where was recorded the smallest standard deviation value.

Ink viscosity increase from low to normal, did not prove theoretical grounds and lead to ink density values increase, instead it produced lower optical ink density values for yellow and black inks, and generated the lowest standard deviations from the reference values.

Table 2: Solid-tone ink density values

Ink viscosity	C	M	Y	K
Low	1.480	1.392	1.423	1.721
Normal	1.498	1.411	1.417	1.709
High	1.554	1.459	1.436	1.759

4.3. Tone Value Increase Analysis

4.3.1. Mechanical Dot Gain of Printing Plates

Table 3, show mechanical dot gain values measured on the offset TPS positive thermal CTP printing plates. Measurements show that all TV are reproduced correctly, without bigger increases. Maximum positive TV deviation is 1.10%, recorded on the 20% TV patch of Yellow separation, and a maximum negative TV deviation is 1.55%, measured on the 50% TV patch of Cyan separation. The lowest overall TVI values are recorded on Cyan separation, while the highest values were recorded on Yellow separation.

Table 3: Mechanical dot gain and TVI values (%)

Ink	10 %	20 %	30 %	40 %	50 %	60 %	70 %	80 %	90 %	TVI [%]
C	10.15	20.30	29.85	38.70	48.45	59.70	68.75	79.40	88.90	- 0.67
M	10.35	20.75	30.90	39.90	48.60	59.60	69.50	79.70	89.70	- 0.08
Y	10.60	21.10	30.55	40.20	49.15	60.10	69.80	80.35	88.90	0.17
K	10.55	20.45	30.70	39.60	48.90	60.25	69.45	79.70	89.75	- 0.04

4.3.2. Tone Value Increase (TVI)

According to ISO 12647-2:2004 standard, obtained TVI values as well as aimed ISO TVI values (gray lines and dashed gray line for black ink separation) which correspond to defined printing conditions as printing process, screen ruling, ink, paper and printing plate types are presented in Figures 2,3,4,5. As a result of lower ink viscosity level application, higher TVI values are produced. Exception is cyan where normal printing pressure level produced the highest TVI values for all considered TV patches, as on 90% TV patch of magenta ink, 70%, 80% and 90% TV patches of yellow ink and 90% TV patch of black ink. The smallest TVI values were with using High ink viscosity, except on 60% and 70% TV patches of black ink separation, which TVI values were higher than those produced using normal ink viscosity level.

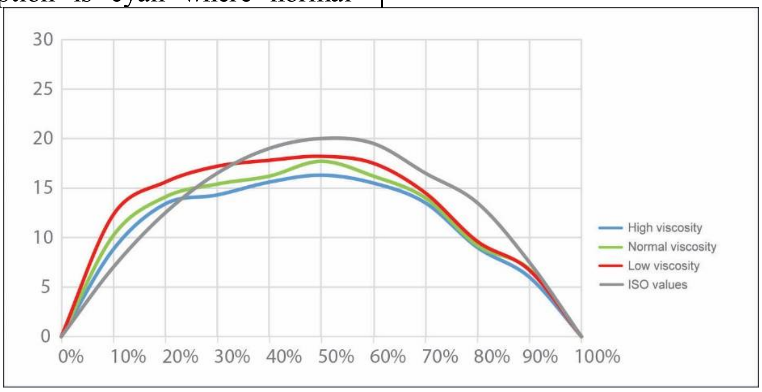

Figure 2: Tone value increase of cyan ink

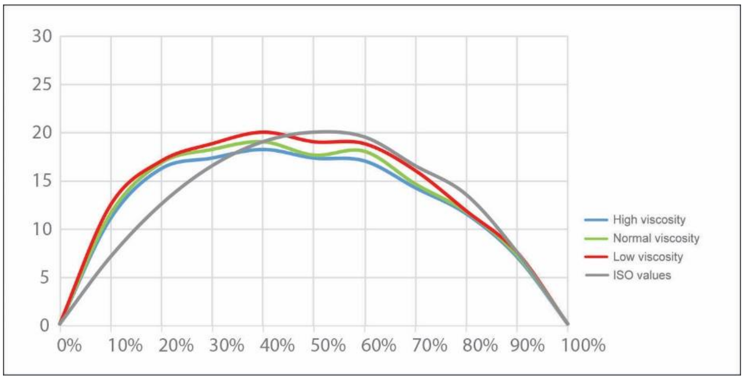

Figure 3: Tone value increase of magenta ink

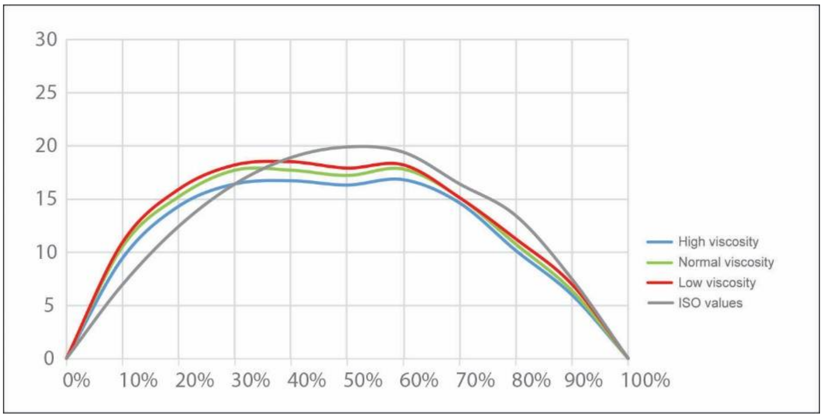

Figure 4: Tone value increase of yellow ink

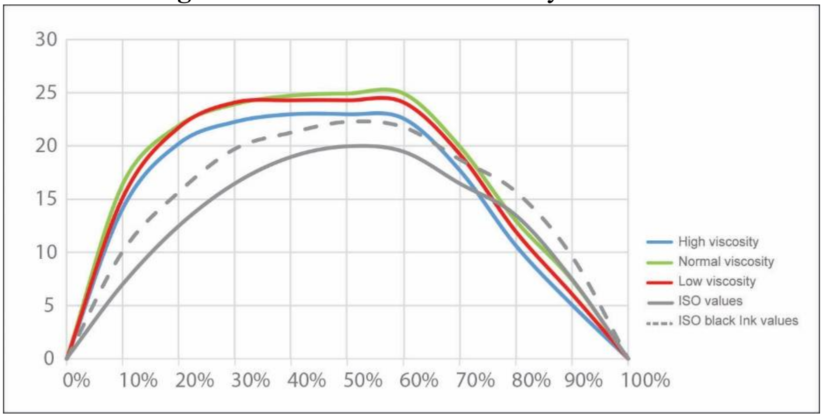

Figure 5: Tone value increase of black ink

The highest TVI values were recorded within the black ink, which is a common case due to the fact that it was printed in the first printing unit and often with greater ink film thickness (Figure 5), even though a black ink was printed using the smallest ink viscosity, considering normal and high ink viscosity settings. The smallest TVI values were obtained on cyan ink, which were printed by the second highest ink viscosity amount and the lowest mechanical dot gain of the plates. Similar TVI was recorded within magenta and yellow inks. Shapes of generated TVI curves for different ink viscosity levels are as well similar for each separation, which shows consistent ink transfer during printing process.

In regard to ISO values for chromatic inks and for black ink, it can be observed that each ink viscosity level produced higher TVI values in highlights (C 10% and 20% TV patches; M 10% - 30% TV patches; Y 10% - 30%) of chromatic colors, while within black ink separation TVI values are higher in middle tones as (K 10% - 60% TV patches). Although, each ink viscosity level produced generally lower TVI values in shadows (70% and 80% TV patches) for all separations.

It is difficult to determine which ink viscosity level produced the best overall performance in terms of TVI, but considering given tolerance values for specific TV patches as well as rest ISO TVI values as a criterion, different ink viscosity levels produced different result for different colors. High ink viscosity level produced the best TVI values for magenta ink, second best for cyan, yellow and black ink separation, normal ink viscosity level showed as a best option for cyan and yellow ink, second best for magenta and third for black ink, normal ink viscosity level generated the best results for black ink.

Analyzed TVI results showed that there is no one specific printing pressure level that can be applied on each printing unit in order to produce the desired TVI results, it was found that various printing units need different ink viscosity level application.

5- Conclusions

Different ink viscosity influenced tone value, as well as that there was no clear trends of how print quality degrades or improve with the same ink viscosity level change for tone value.

Obtained mechanical dot gain values on the plates show that all tone values are reproduced correctly, without bigger increases. Taking into account ISO 12647-2:2004 standard, and reference TVI values for the considered paper type, the most appropriate TVI values were achieved by using different viscosity levels for different inks, low ink viscosity level produced the best TVI values for magenta ink, normal ink viscosity level showed as a best option for cyan and yellow inks, while high ink viscosity level generated the best results for black ink.

It was noticed that, normal ink viscosity level had never produced the best print result within black ink, from the analyzed tone value results it is very difficult to determine which ink viscosity level application is the most efficient one because, as different ink viscosity levels had different impacts on tone value.

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